

LEDAPS Disturbance Products: User's Guide and Algorithm Description (v.2 - August 2007)

Jeffrey G. Masek
NASA GSFC Code 614.4
Greenbelt MD, 20771
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1. Introduction and Algorithm Scope

The goal of the LEDAPS (Landsat Ecosystem Disturbance Adaptive Processing System) project is to map forest disturbance and regrowth across North America, using decadal Landsat imagery. The carbon modeling community is the primary “customer” for the resulting products, although it is expected that ecologists, foresters, and remote sensing scientists will also find them of interest.

The base data set used for the mapping consists of the NASA/Earth Satellite Corporation “GeoCover” product. GeoCover is a global collection of mostly cloud-free, orthorectified Landsat images centered on 1975 (MSS), 1990 (TM), and 2000 (ETM+) epochs (Tucker et al., 2004). GeoCover images were selected based on minimizing cloud cover, imaging near the peak of the local growing season, and imaging close to the central epoch year. As a result of these considerations, individual GeoCover images may come from various years and various seasons. For example, the “1990” global consists mostly of images from 1988 to 1992, but has some images outside this range.

These images are calibrated, converted to top-of-atmosphere (TOA) reflectance, and then atmospherically corrected to surface reflectance using the MODIS/6S approach documented in Vermote et al (1997). Atmospheric correction algorithms and uncertainty analyses for Landsat surface reflectance products are presented elsewhere on the LEDAPS web site.

The initial suite of LEDAPS disturbance products are intended to provide basic information on stand-clearing disturbance and regeneration between the 1990 and 2000 mapping epochs. The type of disturbance is not specified, and non stand-clearing events (thinning, partial harvest, partial defoliation) are not specifically mapped. Later LEDAPS releases will use canopy reflectance modeling to quantify partial canopy removal associated with these “cryptic” disturbance events. However, users should recognize that partial harvest constitutes a significant part of timber removal across the United States (Birdsey and Lewis, 2003).

Stand-clearing disturbance and regrowth are mapped using a “Disturbance Index” (DI) (Healey et al., 2005, in review). This document provides the “as-built” algorithm description for the LEDAPS implementation of the DI approach, and gives results from initial validation studies.

2. Algorithm Description

2.1. General Overview

At a basic level the Disturbance Index (DI) records the normalized spectral distance of any given pixel from a nominal “mature forest” class to a “bare soil” class. The DI is calculated using the Kauth-Thomas tasseled cap (brightness-greenness-wetness) indices for Landsat TM/ETM+ reflectance factor (Kauth and Thomas, 1976; Crist and Ciccone, 1984; Huang et al., 2001):

$$DI = B^* - (G^* + W^*) \quad [1]$$

Where B^* , G^* , and W^* represent brightness, greenness, and wetness indices normalized by the statistics of a mature forest class, such that (for example):

$$B^* = (B - B_f)/B_{fs} \quad [2]$$

Where B_f is the mean Brightness index of the mature forest class, and B_{fs} is the standard deviation of Brightness within the mature forest class. Thus, the DI records the spectral distance of a given pixel from the mature forest class, in units of class standard deviations. DI values greater than ~1 have a high probability of being non-forest.

The LEDAPS algorithm uses the decadal change in DI value (ΔDI) to identify stand-clearing disturbance and regrowth. Large temporal increases in DI represent likely disturbed patches; large decreases represent likely regrowth. However, other land-cover transformations may be inadvertently identified by these ΔDI trends. In particular, agricultural fields can be confused with disturbance if they appear “green” (leaf out) in the first decadal image and barren or tilled in the second. To separate agricultural dynamics from actual forest cover change, we threshold the ΔDI image, and filter it using a forest/non-forest classification.

While the ΔDI approach has proven fairly stable in our initial investigations, it is likely that no one set of processing parameters can produce consistent results across North America. As a result, the LEDAPS disturbance processing is stratified by EPA Level 2 Ecoregion; each Level 2 ecoregion can have a unique set of processing parameters.

This overall processing flow is illustrated in Fig 1. Each step is described more fully below, and representative processing parameter values for the US Mid-Atlantic are given in Table 1.

2.2. Calculation of Tasseled Cap (TC) Indices

The Kauth-Thomas tasseled cap (TC) transformation linearly combines Landsat spectral bands to reduce band-to-band correlation. It is essentially a principal components transformation, but with fixed coefficients supporting average conditions over vegetated mid-latitude landscapes (Kauth and Thomas, 1976). Since LEDAPS is based on atmospherically corrected data, we use the reflectance factor coefficients derived by Crist (1985) rather than the DN-base versions (Crist and Ciccone, 1984) or the top-of-atmosphere version for Landsat-7 (Huang et al., 2001).

2.3. Identification of “Mature Forest Class” and TC Normalization

The “mature forest” class is identified in the 2000 GeoCover ETM+ images using the MODIS 500m Vegetation Continuous Fields (VCF) product. ETM+ pixels with $\text{NDVI} > \text{NDVI_thresh}$ and $\text{VCF treecover} > \text{VCF_thresh}$ are identified as likely forest pixels. The 1990 GeoCover mature forest class is that subset of the ETM+ mature forest class that did not experience significant radiometric change (defined as a change in TC Brightness) between 1990 and 2000.

2.4. Calculation of DI and DDI

Given the population of mature forest pixels from step 2.3, the mean and standard deviation of each tasseled cap component for the class are calculated. Each tasseled cap image plane is then normalized as in Eqs. [1] and [2]. The ΔDI is simply calculated as the temporal change as $\text{DI}_{\text{ETM}} - \text{DI}_{\text{TM}}$. Large positive values of ΔDI correspond to likely disturbance events; large negative values correspond to likely regrowth. These DDI values are thresholded to identify potential disturbance/regrowth ($\Delta\text{DI} > \text{DDI_dist_thresh}$) and regrowth ($\Delta\text{DI} < \text{DDI_regr_thresh}$).

2.5. Thresholding and Forest/Non-Forest Filtering

As noted above, other land-cover transformations may be inadvertently identified by these ΔDI trends, particularly agricultural cropping patterns. The final step filters the DDI map to identify only forest disturbance processes.

For each pixel identified in 2.4 as “potential disturbance/regrowth”, we test if at least one date (e.g. TM or ETM+) can be mapped as forest. We use an internal “fuzzy” classifier to map forest pixels from the reflectance values. This classifier weights three independent parameters:

- The ratio ρ_3/NDVI . Forests should be dark in the red wavelengths and have high NDVI values. Low values of this ratio are likely to be forested
- The 500m VCF treecover value. High treecover percentages make 30m forest pixels more likely
- Low values of DI. The DI parameter itself is an indicator that a given pixel is “close” to the mature forest spectral class.

Each of these parameters is weighted to derive a final probability of membership in the forest class. If at least one date belongs to the forest class, the pixel is considered to represent real disturbance or regrowth.

2.6. Sieve Filtering

A sieve filter is used to remove speckle (<5 contiguous 30m pixels) from the disturbance/regrowth maps. The final maps thus have a minimum mapping area of ~ 0.5 Ha.

Table 1: Parameter values currently used for LEDAPS disturbance mapping.

Parameter	Value
NDVI_thresh	0.80
VCF_thresh	70.00
Δ DI_dist_thresh	1.00
Δ DI_regr_thresh	-0.60

3.0. Validation

LEDAPS disturbance products are being validated by (i) visual comparison with the original Landsat imagery; (ii) visual comparison with high-resolution air photo and satellite imagery; and (iii) statistical comparison with US Forest Service FIA data (stand size distributions, stand age distributions, volumetric removals). At this point, few validation results have been prepared.

We have performed an initial comparison of the automated LEDAPS disturbance mapping with a version created through visual analysis of the raw Landsat images for path 15 row 34 (Central Virginia, Fig. 2). In general there is a close correspondence between the two. Treating the visual analysis as “truth” gives an overall accuracy of 87%, an omission error of 18%, and an commission error of 20%. The errors of omission mostly result from disturbance events that were missed. Often these patches were cleared shortly after the TM image was acquired; by the time the ETM+ image was acquired ~10 years later, the patch had substantially regrown. Errors of commission were usually agricultural fields misidentified as disturbance or regrowth.

4.0. Known Issues and Proposed Solutions

Clouds and cloud shadows are poorly captured by the LEDAPS cloud mask, and may be confused with disturbance/regrowth.

Solution: An improved cloud/shadow mask is being developed, based on the MODIS land reflectance processing algorithm.

The current forest/non-forest filtering uses the internal “fuzzy” classifier, which may fail for some crops at peak greenness, and may screen out changes near urban areas. As a result some croplands are identified as disturbance/regrowth, and some urban development is not identified as disturbance

Solution: Future releases will use the 30-meter resolution 1992 and 2000 MRLC National Land Cover Database (NLCD) to discriminate forest from non-forest for the United States.

References

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Fig. 1: Schematic overview of Disturbance Index algorithm processing steps.

Overview of Disturbance Index Algorithm

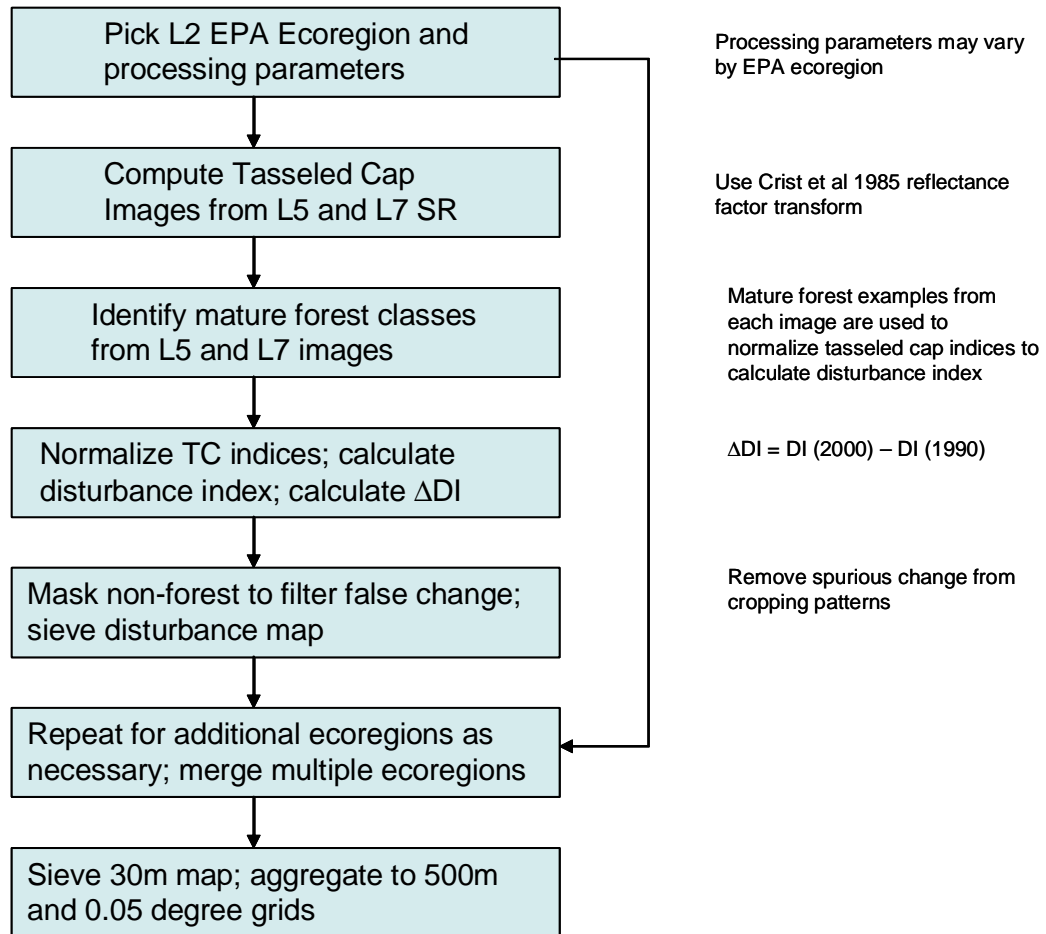


Fig. 2: Comparison between disturbance (purple) and regrowth (green) mapped through visual interpretation of Landsat imagery and automated LEDAPS algorithm, for Central Virginia (p15, r34). Upper-left: May 1990 Landsat-5 image (543 RGB composite); Upper-right: September 1999 Landsat-7 image; Lower-left: automated LEDAPS disturbance/regrowth map; Lower-right: disturbance/regrowth map generated from visual inspection. Scale bar is 4km.

